CLAIMS

What is claimed is:

1. An apparatus for measuring one or more parameters of a diffracting structure on a sample, said apparatus comprising:

a radiation source that emits broadband radiation;

a polarizing element, said radiation passing through said polarizing element toward said sample, said radiation being normally incident on and reflected off said diffracting structure on said sample, said reflected radiation passing through said polarizing element, at least one of said polarizing element and said sample are rotatable to produce a relative rotation between said polarizing element and said diffracting structure; and

a spectrograph that detects the intensity of spectral components of said reflected radiation after passing through said polarizing element at a plurality of polarization orientations between said polarizing element and said diffracting structure.

2. The apparatus of Claim 1, wherein said spectrograph produces a spectrograph signal for said spectral components and a plurality of polarization orientations, said apparatus further comprising a computer system for analyzing said spectrograph signal to determine said one or more parameters of said diffracting structure on said sample, said computer system comprising:

at least one computer connected to said spectrograph to receive said spectrograph signal; and

a computer program executed by said at least one computer, wherein said computer program includes instructions for:

extracting spectral information from said spectrograph signal.

3. The apparatus of Claim 2, wherein said computer program further comprises instructions for:

constructing an optical model simulating said diffracting structure using at least one variable parameter;

calculating spectral information for said optical model; and

curve fitting said calculated spectral information to said extracted spectral information to determine said one or more parameters of said diffracting structure on said sample.

4. The apparatus of Claim 3, wherein said computer instructions for curve fitting comprise computer instructions for using a non-linear regression routine.

5. The apparatus of Claim 3, wherein said computer instructions for curve fitting comprise computer instructions for:

comparing said extracted spectral information and said spectral information for said optical model;

adjusting said at least one variable parameter of said optical model;

recalculating spectral information for said optical model;

comparing said extracted spectral information and said recalculated spectral information for said optical model; and

repeatably adjusting said at least one variable parameter, recalculating spectral information for said optical model, and comparing said extracted spectral information and said recalculated spectral information for said optical model until an acceptable fit is achieved.

6. The apparatus of Claim 3, wherein said computer instructions for constructing an optical model and calculating spectral information for said optical model comprise computer instructions for using rigorous coupled-wave analysis.

7. The apparatus of Claim 2, wherein said computer instructions for extracting spectral information from said spectrograph signal comprise computer instructions for:

calculating the sample reflectance for a plurality of wavelengths of said radiation and a plurality of polarization orientations of said polarizing element relative to said diffracting structure; and

curve fitting said sample reflectance for said plurality of wavelengths and said plurality of positions with:

$$R(\Theta) = A \cdot \cos^4(\phi - \Theta) + B \cdot \sin^4(\phi - \Theta) + C \cdot \cos^2(\phi - \Theta) \cdot \sin^2(\phi - \Theta)$$

where R(Θ) is the measured reflectance at one wavelengths, Θ is the polarization orientation of said polarizing element with respect to said diffracting structure, and ϕ, A, B, and C, measurable, to obtain said spectral information.

8. The apparatus of Claim 7, wherein said computer instructions for curve fitting comprise computer instructions for using a non-linear regression routine.

9. The apparatus of Claim 1, wherein said spectrograph comprises:

a dispersing element that disperses said polarized beam into spectral components; and

an array of detector pixels that detect the intensity of said spectral components.

10. The apparatus of Claim 1, wherein said polarizing element is a rotatable polarizing element that rotates relative to said diffracting structure.

11. The apparatus of Claim 1, said apparatus further comprising a sample stage, said sample being held on said sample stage, wherein said sample stage rotates said diffracting structure relative to said polarizing element.

12. The apparatus of Claim 1, said apparatus further comprising an r-θ sample stage, said sample being held on said r-θ sample stage.

13. A method of measuring at least one parameter of a diffracting structure, said method comprising:

(a) passing broadband radiation through a polarizing element to produce polarized radiation;

(b) directing said polarized radiation to be normally incident with said diffracting structure, said polarized radiation being reflected off by said diffracting structure on said sample;

(c) analyzing the reflected radiation with said polarizing element to produce an output beam with a polarity orientation;

(d) detecting the intensity of spectral components of said output beam;

(e) producing a relative rotation between said polarizing element and said diffracting structure to alter the orientation of said polarized element relative to said diffracting structure and repeating steps a through d;

(f) repeating step e for a plurality of orientations of said polarizing element and said diffracting structure; and

(f) using said detected intensities of said spectral components of said output beam for a plurality of orientations to determine said at least one parameter of said diffracting structure.

14. The method of Claim 13, further comprising:

generating a reference database of different diffracting structures having at least one variable parameter related to a plurality of wavelengths and a plurality of orientations;

comparing said detected intensities of said spectral components to said database to determine said at least one parameter of said diffracting structure.

15. The method of Claim 13, wherein producing a relative rotation between said polarizing element and said diffracting structure comprises rotating said polarizing element.

16. The method of Claim 13, wherein producing a relative rotation between said polarizing element and said diffracting structure comprises rotating said diffracting structure.

17. An apparatus for measuring one or more parameters of a diffracting structure on a sample, said apparatus comprising:

a metrology device that measures the reflectance of said diffracting structure on said sample;

and a computer system for analyzing said reflectance to determine said one or more parameters of said diffracting structure on said sample, said computer system comprising:

at least one computer connected to said metrology device; and

a computer program executed by said at least one computer, wherein said computer program includes instructions for:

extracting spectral information from said reflectance measurement;

constructing an optical model simulating said diffracting structure using at least one variable parameter;

calculating spectral information for said optical model; and

using non-linear regression to curve fit said calculated spectral information to said extracted spectral information to determine said one or more parameters of said diffracting structure on said sample.

18. The apparatus of Claim 17, wherein said metrology device measures the reflectance at a plurality of wavelengths and a plurality of polarization orientations, wherein said computer instructions for extracting spectral information from said reflectance measurement comprise computer instructions for:

curve fitting said sample reflectance for said plurality of wavelengths and said plurality of positions with:

$$R(\Theta) = A \cdot \cos^4(\phi - \Theta) + B \cdot \sin^4(\phi - \Theta) + C \cdot \cos^2(\phi - \Theta) \cdot \sin^2(\phi - \Theta)$$

where $R(\Theta)$ is the measured reflectance at one wavelengths, Θ is the polarization orientation of said polarizing element with respect to said diffracting structure, and ϕ, A, B, and C, measurable, to obtain said spectral information.

19. The apparatus of Claim 18, wherein said computer instructions for curve fitting comprise computer instructions for using a non-linear regression routine.

20. The apparatus of Claim 17, wherein said metrology device measures the reflectance at a plurality of wavelengths and a plurality of polarization orientations, wherein said computer instructions for extracting spectral information from said reflectance measurement comprise computer instructions for directly calculating said spectral information from said reflectance measurement.

21. The apparatus of Claim 17, wherein said computer instructions for curve fitting comprise computer instructions for:

comparing said extracted spectral information and said spectral information for said optical model;

adjusting said at least one variable parameter of said optical model;

recalculating spectral information for said optical model;

comparing said extracted spectral information and said recalculated spectral information for said optical model; and

repeating adjusting said at least one variable, recalculating spectral information for said optical model, and comparing said extracted spectral information and said recalculated spectral information for said optical model until an acceptable fit is achieved.

22. The apparatus of Claim 17, wherein said computer instructions for constructing an optical model and calculating spectral information for said optical model comprise computer instructions for using rigorous coupled-wave analysis.

23. A method of determining one or more parameters of a diffracting structure on a sample, said method comprising:

acquiring a reflectance signal from said diffracting structure on said sample;

extracting spectral information from said reflectance signal;

constructing an optical model simulating said diffracting structure using variable one or more parameters;

calculating spectral information from said optical model;

curve fitting said extracted spectral information and said calculated spectral information and adjusting said variable one or more parameters to determine said one or more parameters of said diffracting structure on said sample.

24. The method of Claim 23, wherein curve fitting comprises:

comparing said extracted spectral information and said spectral information for said optical model;

adjusting said variable one or more parameters of said optical model;

recalculating spectral information for said optical model;

comparing said extracted spectral information and said recalculated spectral information for said optical model; and

repeatably adjusting said variable one or more parameters, recalculating spectral information for said optical model, and comparing said extracted spectral information and said recalculated spectral information for said optical model until an acceptable fit is achieved.

25. The method of Claim 23, wherein constructing an optical model and calculating spectral information for said optical model comprises using rigorous coupled-wave analysis.

26. A method of determining one or more parameters of a diffracting structure on a sample, said method comprising:

acquiring a reflectance signal from said diffracting structure on said sample;

extracting spectral information from said reflectance signal;

performing a rigorous coupled-wave analysis using non-linear regression with said extracted spectral information to determine said one or more parameters of said diffracting structure on said sample.

27. An apparatus for measuring one or more parameters of a diffracting structure on a sample, said apparatus comprising:

a radiation source that emits broadband radiation, said radiation is normally incident on said diffracting structure;

a polarizing element in the beam path of said broadband radiation;

an r-θ sample stage for holding said sample with said diffracting structure; and

a spectrograph that detects the intensity of spectral components of radiation reflected off said diffracting structure.

28. The apparatus of Claim 27, wherein said radiation passes through said polarizing element toward said sample, said radiation is reflected off said diffracting structure on said sample, said reflected radiation passing through said polarizing element, said polarizing element being rotatable to produce a relative rotation between said polarizing element and said diffracting structure.

29. The apparatus of Claim 28, wherein said spectrograph detects the intensity of spectral components of said reflected radiation after passing through said polarizing element at a plurality of polarization orientations between said polarizing element and said diffracting structure.